Astronomy & Astrophysics manuscript no.
(DOI: will be inserted by hand later)

February 1, 2008

Superhump-like variation during the anomalous state of SU UMa

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Received / accepted

Abstract. We observed an anomalously outbursting state of SU UMa which occurred in 1992. Time-resolved photometry revealed the presence of signals with a period of 0.0832±0.0019 d, which is 3.6σ longer than the orbital period (0.07635 d) of this system. We attributed this signal to superhumps, based on its deviation from the orbital period and its characteristic profile. During this anomalous state of SU UMa, normal outbursts were almost suppressed, in spite of relatively regular occurrences of superoutbursts. We consider that an ensuing tidally unstable state following the preceding superoutburst can be a viable mechanism to effectively suppress normal outbursts, resulting in an anomalously outbursting state.

Key words. Accretion, accretion disks — novae, cataclysmic variables — Stars: dwarf novae — Stars: individual (SU UMa)

1. Introduction

SU UMa is the prototype of SU UMa-type dwarf novae (for a recent review of SU UMa-type stars and their observational properties, see Warner 1995). Although SU UMa shows typical superoutbursts and associated superhumps as in other SU UMa-type dwarf novae (Udalski, 1990), the star is also known to sometimes show anomalous states lacking superoutbursts, or even normal outbursts (cf. Rosenzweig et al. 2000). According to Rosenzweig et al. (2000), the period of 1980–1983 was the most remarkable, when SU UMa almost completely stopped outbursting. Several instances have been known, that SU UMa showed a lesser degree of anomalously outbursting state. February, 1992 was another such period (cf. Rosenzweig et al. 2000), when SU UMa ceased to show normal outbursts. During that period, the mean brightness of SU UMa was observed brighter than the averaged quiescent level.

2. Observation

We obtained time-resolved CCD photometric runs on three night in 1992 February, when SU UMa was reported to be in an anomalous state. The long observation on February 17 was done between BJD 2448669.959 and 2448670.252, covering 7 hours.

Two shorter runs were done under less favorable conditions before and after this night. We used a CCD camera (Thomson TH 7882, 576 × 384 pixels, on-chip 3×3 binning adopted) attached to the Cassegrain focus of the 60 cm reflector (focal length=4.8 m) at Ouda Station, Kyoto University (Ohtani et al., 1992). An interference filter was used which had been designed to reproduce the Johnson V band. The exposure time was 30 s. The frames were first corrected for standard de-biasing and flat fielding, and were then processed by a microcomputer-based aperture photometry package developed by the author. The magnitudes of the object were determined relative to GSC 4129.95 (V=13.38, $B-V$=+0.75), whose constancy during the run was confirmed using GSC 4129.224. The magnitude of the comparison star is taken from Misselt (1996). Barycentric corrections to the observed times were applied before the following analysis. Table 1 lists the log of observations, together with nightly averaged magnitudes.

Table 1. Nightly averaged magnitudes of SU UMa

Start[a]	End[a]	Mean mag[b]	Error[c]	N[d]
48868.906	48869.190	−0.065	0.009	119
48869.959	48870.252	0.315	0.006	430
48870.925	48871.138	1.033	0.012	274

[a] BJD−2400000.
[b] Relative magnitude to GSC 4129.9.
[c] Standard error of nightly average.
[d] Number of frames.

Fig. 1 shows the overall light curve of this observation. SU UMa was fading from a small outburst (or a minor brightening), not apparently recorded in Rosenzweig et al. (2000), probably because of the faintness of the peak brightness (V ~13.3). Since most of recent outbursts of SU UMa reach V=12, such a faint outburst was al-

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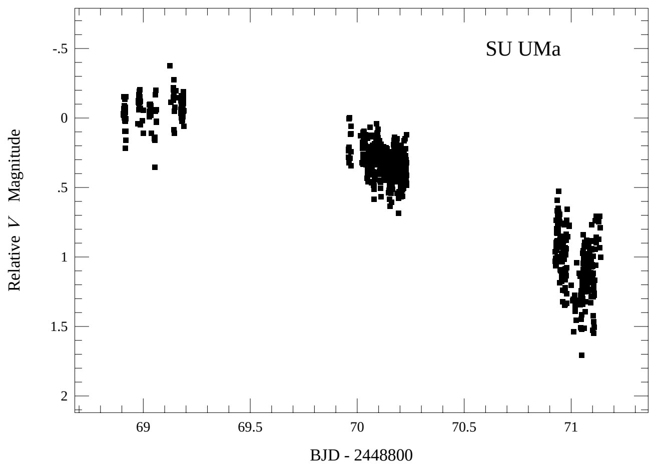

Fig. 1. Light curve of a faint outburst of SU UMa in 1992 February.

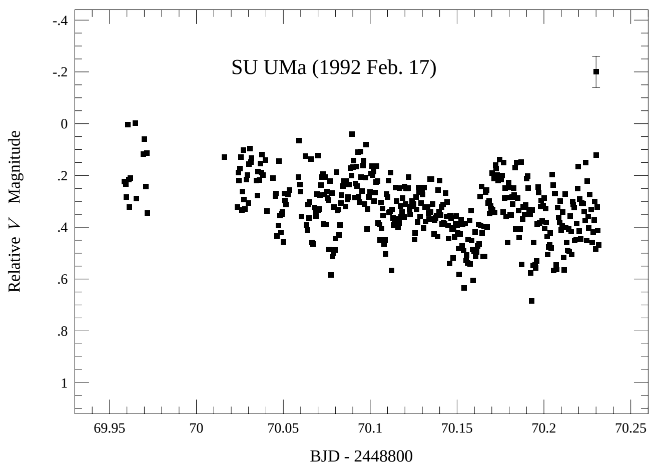

Fig. 2. Light curve on 1992 February 17.

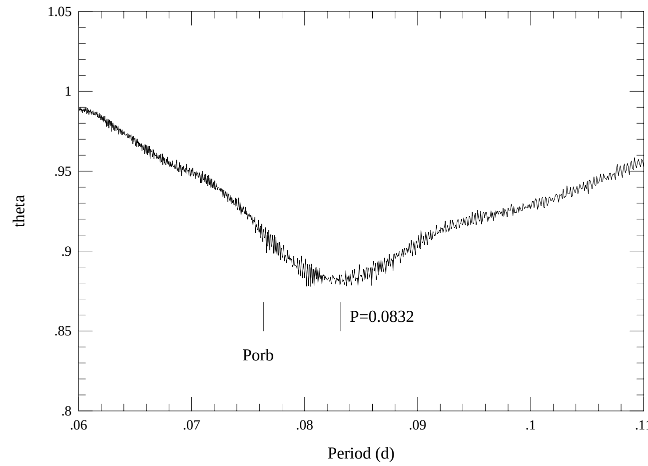

Fig. 3. Period analysis of SU UMa (1992 February 17).

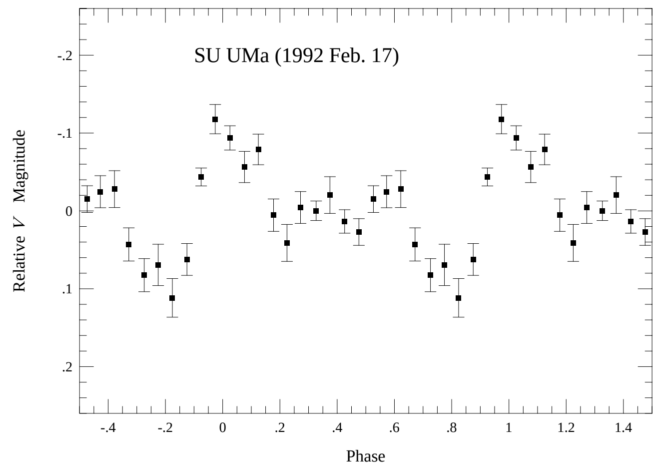

Fig. 4. Phase-averaged light curve (1992 February 17).

ready anomalous. The enlargement of the February 17 light curve (Fig. 2) shows hump-like modulations, with an approximate period close to, but slightly longer than, the orbital period ($P_{\rm orb}$=0.07635 d, Thorstensen et al. (1986)). The observation on the preceding night was unfortunately affected by a large gap owing to clouds; on the next night, the object had faded and again moderately affected by clouds. Only high-quality February 17 observations were used for the subsequent period analysis.

The observations on February 17 were analyzed, after removing a linear trend of decline, with the Phase Dispersion Minimization (PDM) method (Stellingwerf, 1978). The resultant theta diagram and phase-averaged light curve are shown in Figs. 3 and 4, respectively.

3. Result and discussion

The period analysis strongly supports that presence of the period of 0.0832±0.0019 d. The error of the period was estimated using the application of Lafler-Kinman class of methods by Fernie (1989). Although the error of period estimation is rather large due to the limited length of a single-night baseline, the period is 3.6σ longer than the orbital period, and is 2.1σ longer than the superhump period by Udalski (1990). Since superhump periods can vary to a considerable extent (e.g. Kato 2001a), the present periodicity, which is significantly longer than the orbital period, is more regarded as a variety of superhumps, rather than the one reflecting the orbital period.

The hump profile shown in Fig. 4. A rapid rise and slower fade, and the presence of a secondary hump at phase 0.6 (cf. Udalski (1990) for the discussion of secondary superhumps during a superoutburst), are also very characteristic of superhumps. Such appearance of the superhump signal may be related to the anomalous state of SU UMa.

Rosenzweig et al. (2000) argued that the complete cessation of outburst in the period of 1980–1983 was probably caused by a strong variation of mass-transfer rates ($\dot{M}$). This interpretation, however, does not seem to adequately explain the 1992 anomalous state, since the interval of superoutbursts (labeled S020 on JD 2448784 and S021 on JD 2449047 in Rosenzweig et al. (2000)) just before and after this anomalous state was 263 d, which is only slightly longer than the typical value of this object (see Fig. 5 of Rosenzweig et al. (2000)). This interval is

also a very typical value as seen in other SU UMa-type dwarf novae (Nogami et al., 1997). Since the length of a supercycle is primarily governed by the transferred angular momentum from the secondary star (Osaki, 1989), the interval of successive superoutbursts is roughly inversely proportional to $\dot{M}$ (Ichikawa & Osaki, 1994). This suggests that $\dot{M}$ was relatively normal during this anomalous state, and that normal outbursts may have been somehow suppressed even under the condition of a usual $\dot{M}$.

There are some known SU UMa-type dwarf novae which show a permanently, or temporarily, reduced frequency of normal outbursts, in contrast to their high frequency of superoutbursts (V503 Cyg: Harvey et al. 1995, Ishioka et al. in preparation; V1113 Cyg: Kato 2001b). The presence of active and inactive phases in V1113 Cyg, in terms of the frequency of normal outbursts, while maintaining the supercycle length, seems to require an unknown mechanism which effectively suppresses normal outbursts (Kato, 2001b).

The present discovery of a signal, which can be attributed to superhumps, during a similarly anomalously outbursting state of SU UMa provides an additional clue to this phenomenon. SU UMa during anomalous outbursting states may more or less resemble permanent superhumpers (cf. Osaki 1996), which do not show strong dwarf nova-type outbursts, but show superhumps. The accretion disk in permanent superhumpers is believed to be hot enough to suppress usual thermal instability, which is responsible for normal outbursts, but is tidally unstable, giving rise to permanent superhumps (Osaki, 1996). Altough it is not yet clear whether such a condition is met during this anomalously outbursting state of SU UMa, or whether a similar explanation can be applicable to SU UMa-type dwarf novae with strongly variable activities, the possibility of an ensuing tidally unstable state following the preceding superoutburst can be a viable mechanism to effectively suppress normal outbursts. Since such anomalous states are known to be rather infrequent, intensive target-of-opportunity observations are strongly encouraged when future occurrence of such a state is recognized.

This work is partly supported by a grant-in aid (13640239) from the Japanese Ministry of Education, Culture, Sports, Science and Technology.

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